

WE CLAIM:

1. A manipulation system for cardiac surgery of the class wherein a gross support means for engaging a beating heart supports the heart when the heart is located and oriented for surgery, wherein the improvement comprises:

the gross support means being located at the base of the heart and including a head which is sized and shaped to cradle the myocardium of the left ventricle along the arterialventricular groove; and

a suspension head for lifting the heart and which is located near the apical region of the heart and at least partially overlying the right ventricle.

2. In a manipulation system for cardiac surgery which includes means for engaging a selected section of the heart to immobilize that selected section as a surgery target while permitting non-engaged sections of the heart to move in a manner whereby essentially unabated cardiac output is maintained while the heart is regionally immobilized, wherein the improvement comprises:

a suspension head means for applying suction to the surface of the beating heart to lift the heart and which is located near the apical region of the heart, said suspension head including a head abutting the surface of the beating heart, said head having means for accommodating multiplanar surface movement of the beating heart while maintaining suction application to the surface of the beating heart, said head including means for preventing heart tissue from clogging a fluid connection between

a source of suction applied to the heart via said head and said heart, said suspension head further including means for accommodating multiplanar movement of the beating heart.

3. A manipulation system for cardiac surgery comprising:

a gross support means for engaging a beating heart to support the heart when the heart has been oriented into an unnatural position or orientation for cardiac surgery,

means for engaging a selected section of the heart to immobilize that selected section as a surgery target while permitting non-engaged sections of the heart to move in a manner whereby essentially unabated cardiac output is maintained while the heart is regionally immobilized,

a head on the gross support means, said head including a first chamber and a second chamber for fluidically connecting the first chamber to a source of suction and grid mesh means for preventing heart tissue from interfering with suction being applied to the heart via said head.

4. The improvement defined in Claim 3 further including a mesh grid attached to said suction cup adjacent to said shoulder and spanning said first chamber for preventing heart tissue from clogging the fluid connection between the second chamber and the source of suction.

5. The improvement defined in Claim 3 further including a suspension head for lifting the heart and which is located near

the apex of the heart adjacent to the right ventricle and which includes a flexible head.

6. The improvement defined in Claim 5 wherein said suspension head further includes a multi-section suction cup, said suction cup including a first chamber having a flexible rim for engaging the heart, a second chamber for fluidically connecting the first chamber to a source of suction, said second chamber having a size that is different from the size of said first chamber, said flexible rim being flexible in a plurality of planes to accommodate multiplanar movement of the surface of the beating heart without breaking contact between the surface of the heart and the suction cup, and means for accommodating multiplanar movement of the beating heart during beating heart surgery.

7. The improvement defined in Claim 2 wherein the means for engaging a selected section of the heart includes a multi-section suction cup having a first chamber having a flexible rim for engaging the heart, a second chamber for fluidically connecting the first chamber of the suction cup of the means for engaging a selected section of the heart to a source of suction, the second chamber of the suction cup of the means for engaging a selected section of the heart having a size that is different from the size of said first chamber of the suction cup of the means for engaging a selected section of the heart, the flexible rim of the suction cup of the means for engaging a selected section of the heart being flexible in a plurality of planes to accommodate

multiplanar movement of the surface of the beating heart without breaking contact between the surface of the heart and the flexible rim of the suction cup of the means for engaging a selected section of the heart.

8. The improvement defined in Claim 2 wherein the retractor further includes a gross support means and the improvement further includes a malleable rod on the gross support means.
9. The improvement defined in Claim 1 wherein the improvement further includes a frame means for supporting said gross support and said suspension head.
10. The improvement defined in Claim 9 said frame means includes means for mounting said frame within the patient's thoracic cavity.
11. The improvement defined in Claim 10 wherein said frame means further includes a cross bar on which said means for mounting said frame within the patient's thoracic cavity is mounted.
12. The improvement defined in Claim 6 wherein said suction cup includes a shoulder.
13. The improvement defined in Claim 1 wherein said gross support means further includes a handle thereon, said handle having a length sufficient to allow placement of said gross support means

at the base of the heart from above the heart when said gross support means is in place on the patient's heart.

14. The improvement defined in Claim 9 wherein said frame means at least partially surrounds the patient's heart when said gross support means is in place on the patient's heart.

15. The improvement defined in Claim 1 wherein said gross support means is located adjacent to the left atrium.

16. The improvement defined in Claim 15 further including a source of vacuum fluidically connected to said cup-shaped element.

17. A heart manipulation system for use in cardiac surgery comprising:

- a frame that is located inside a patient during beating heart surgery and which includes means for engaging the pericardial cavity of the patient for mounting said frame on the patient to move with the patient if the patient is moved or re-oriented during surgery;

- a source of suction;

- a suspension head movably mounted on said frame for lifting the heart and which is located near the apical region of the right ventricle to prevent collapse of the right ventricle during manipulation of the heart and at least partially overlying the right ventricle and which includes a flexible means for

permitting multiplanar relative movement between the beating heart and means mounting the suspension head on said frame means, said suspension head including a suction cup connected to the source of suction and which includes a flexible rim engaging the myocardium of the heart and being flexible in a plurality of planes so multiplanar movement of the myocardium during operation of the heart will be accommodated by said flexible rim whereby suction applied to the myocardium by said suction cup will not be broken by separation of the myocardium from the suction cup, said suction cup further including mesh grid means for preventing heart tissue from interfering with suction being applied to the myocardium via said suction cup;

a means for locally engaging a selected section of the heart and locally immobilizing the heart adjacent to a surgery target so the heart is supported and free to operate during surgery while it is also locally immobilized at the surgery target with non-engaged sections of the heart free to move in a manner whereby essentially unabated cardiac output is maintained while the heart is locally immobilized, and further including a suction cup connected to the source of suction and which includes a flexible rim engaging the myocardium of the heart and being flexible in a plurality of planes so multiplanar movement of the myocardium during operation of the heart will be accommodated by the flexible rim of said means for locally engaging a selected section of the heart whereby suction applied to the myocardium by the suction cup of said means for locally engaging a selected section of the heart will not be broken by

separation of the myocardium from the suction cup of said means for locally engaging a selected section of the heart, said suction cup of said means for locally engaging a selected section of the heart further including mesh grid means for preventing heart tissue from interfering with suction being applied to the myocardium via said suction cup of said means for locally engaging a selected section of the heart; and

a gross support means movably mounted on said frame for engaging the heart to support the heart when the heart is oriented for surgery and which is located at the base of the heart and which cradles the myocardium of the left ventricle along the arterialventricular groove and which includes means for movably connecting said gross support means to said frame, the gross support means supporting the mitral valve annulus to maintain competent mitral valve function and is placed beneath an infolded section of myocardium, said gross support means including a handle which extends outside of the patient during surgery for adjusting the location of said gross support means, and further including a head having a malleable rod means for connecting said head to said means for mounting said gross support means on said frame, said head including a plurality of sections which are movable relative to each other and means for maintaining said sections in a selected relative orientation, said head further including a means for applying suction from said source of suction to the heart and which includes mesh grid means for preventing heart tissue from interfering with suction applied by said suspension head to the heart.

18. A heart manipulation system for use in cardiac surgery comprising:

a frame which is located inside a patient during beating heart surgery and which is mounted on the patient to move with the patient;

a suspension head mounted on said frame for lifting the beating heart and which includes a flexible head, said flexible head including a flexible rim, said flexible rim being flexible in a plurality of planes to accommodate multiplanar movement of the surface of the beating heart without breaking contact between the surface of the heart and the flexible rim, and means for accommodating multiplanar movement of the beating heart during beating heart surgery; and

means for engaging a selected section of the heart to immobilize that selected section as a surgery target while permitting non-engaged sections of the heart to move in a manner whereby essentially unabated cardiac output is maintained while the heart is locally immobilized.

19. The improvement defined in Claim 1 wherein the improvement further includes means for engaging a selected section of the heart to immobilize that selected section as a surgery target while permitting non-engaged sections of the heart to move in a manner whereby essentially unabated cardiac output is maintained while the heart is regionally immobilized.

20. The improvement defined in Claim 18 further including a head on the gross support means, said head including a first chamber and a second chamber for fluidically connecting the first chamber to a source of suction, said second chamber having a size that is different from the size of said first chamber.

21. The improvement defined in Claim 17 wherein said frame at least partially surrounds the patient's heart.

22. The improvement defined in Claim 19 further including a multi-section suction cup on said means for engaging a selected section of the heart.

23. A method of performing heart surgery comprising steps of:

slightly infolding the left atrium of a heart adjacent to the base of the heart;

engaging the heart under the edge of the myocardium at the base of the heart to tilt and lift the heart; and

engaging the heart near the apex of the heart to lift the heart and preventing right ventricle collapse.

24. The method defined in Claim 23 further including a step of engaging a selected section of the heart and immobilizing that selected section as a surgery target while permitting non-engaged sections of the heart to move and permitting essentially unabated cardiac output to be maintained while the heart is regionally immobilized.

25. The method defined in Claim 23 wherein the step of engaging the heart includes a step of applying suction to the myocardium.
26. The method defined in Claim 24 wherein the step of engaging a selected section of the heart includes a step of applying suction to the myocardium adjacent to the selected section.
27. The improvement defined in Claim 22 wherein said multi-section suction cup includes a first chamber having a flexible rim for engaging the heart, a second chamber for fluidically connecting the first chamber to a source of suction, said second chamber having a size that is different from the size of said first chamber, and a shoulder at the connection between said first chamber and said second chamber, said flexible rim being flexible in a plurality of planes to accommodate multiplanar movement of the surface of the beating heart without breaking contact between the surface of the heart and the flexible rim.
28. The improvement defined in Claim 3 wherein the means for engaging a selected section of the heart further includes a multi-section suction cup which includes a first chamber having a flexible rim for engaging the heart, a second chamber for fluidically connecting the first chamber to a source of suction, said second chamber having a size that is different from the size of said first chamber, said flexible rim being flexible in a plurality of planes to accommodate multiplanar movement of the surface of the beating heart without breaking contact between the

surface of the heart and the flexible rim.

29. A manipulation system for use in cardiac surgery comprising:

a gross support means for engaging and supporting a beating heart when the heart is located and oriented for surgery and which is located at the base of the heart and engages the beating heart at a location that supports the mitral valve annulus and which includes a flexible head which is sized and shaped to extend along the arterialventricular groove of the heart;

means for immobilizing the heart adjacent to a surgery target so the heart is supported and free to operate during surgery while it is also locally immobilized at the surgery target; and

a suspension head for lifting the heart and which is located near the apex of the heart and which includes a flexible head.

30. A manipulation system for use in cardiac surgery comprising:

means for supporting a beating heart adjacent to a surgery target so the heart is free to operate during surgery while it is also locally immobilized at the surgery target; and

a suspension head for lifting the beating heart including a heart attachment means for attaching said suspension head to the heart, said heart attachment means including a flexible heart-engaging portion that is flexible in a plurality of planes to accommodate heart surface multiplanar movement during beating of the heart.

31. A manipulation system for use in minimally invasive cardiac surgery comprising:

means for supporting a beating heart adjacent to a surgery target so the heart is free to operate during surgery while it is also locally immobilized at the surgery target; and

a suspension head for lifting the beating heart including a suction cup means for attaching said suspension head to the heart; said suction cup means including a flexible heart-engaging portion that is flexible in a plurality of planes to accommodate heart surface multiplanar movement during beating of the heart.

32. A suction cup for use in cardiac surgery comprising:

a first chamber having a flexible rim for engaging the heart, a second chamber for fluidically connecting the first chamber to a source of suction, said rim being flexible in a plurality of planes to accommodate multiplanar movement of the surface of the beating heart without breaking suction applied to the heart via said first chamber.

33. The suction cup defined in Claim 32 further including a mesh grid element connected to said suction cup spanning said first chamber for preventing heart tissue from clogging the fluid connection between the first chamber and the source of suction.

34. The improvement defined in Claim 1 further including a flexible means on said suspension head for permitting the heart to move in a plurality of planes.

35. The improvement defined in Claim 1 further including a malleable section on said gross support means.
36. The improvement defined in Claim 18 further including a flexible means on said suspension head for permitting the heart to move in a plurality of planes.
37. The improvement defined in Claim 18 further including a malleable section on said gross support means.
38. The improvement defined in Claim 3 further including a flexible means on said suspension head for permitting the heart to move in a plurality of planes.
39. The improvement defined in Claim 3 further including a malleable section on said gross support means.
40. The manipulation system defined in Claim 30 further including a gross support means for engaging and supporting a heart when the heart is located and oriented for surgery and which cradles myocardium of the left ventricle along the arterialventricular groove.
41. The manipulation system defined in Claim 30 wherein said suspension head further includes means on said suction cup for permitting said suction cup to move in a plurality of directions to accommodate beating heart movement.

42. The manipulation system defined in Claim 30 wherein said suction cup further includes means for preventing heart tissue from interrupting suction applied by said suction cup.

43. The manipulation system defined in Claim 18 further including a support means for engaging the heart to support the heart when the heart is oriented for surgery and being mounted on said frame and cradling myocardium of the left ventricle along the arterialventricular groove.

44. A manipulation system for use in minimally invasive cardiac surgery comprising:

a gross support means for engaging and supporting a beating heart when the heart is located and oriented for surgery and which is located so mitral valve operation of the beating heart is not interrupted;

means for immobilizing the heart adjacent to a surgery target so the heart is supported and free to operate during surgery while it is also locally immobilized at the surgery target; and

a suspension head for lifting the beating heart and which is located near the apex of the heart.

45. The system defined in Claim 17 wherein the flexible head of said suspension means includes a first chamber for engaging the myocardium of the heart, a second chamber for fluidically connecting the first chamber to said source of suction, the

second chamber of said suspension head having a size that is different from the size of the first chamber said suspension head, the mesh grid element of said suspension head being connected to said suspension head and spanning the first chamber of said suspension head for preventing heart tissue from interfering with suction applied to the heart via said suspension head.

46. The manipulation system defined in Claim 17 wherein the suction cup of said means for locally immobilizing the heart is a multi-section suction cup which includes a first chamber having a flexible rim for engaging the heart, a second chamber for fluidically connecting the first chamber of the means for locally immobilizing the heart to the source of suction, the second chamber of the suction cup of the means for locally immobilizing the heart having a size that is different from the size of the first chamber of the suction cup of the means for locally immobilizing the heart, and a shoulder at the connection between first and second chambers of the suction cup of the means for locally immobilizing the heart, and a mesh grid element connected to the suction cup on said means for immobilizing the heart adjacent to the shoulder of the suction cup of the means for immobilizing the heart and spanning the first chamber of the suction cup of the means for immobilizing the heart, the flexible rim of the suction cup on the means for locally engaging a selected section of the heart being flexible in a plurality of planes to accommodate multiplanar movement of the surface of the

beating heart without breaking contact between the surface of the heart and the flexible rim of the suction cup on the means for engaging a selected section of the heart.

47. The system defined in Claim 17 wherein said flexible means on the suspension head includes a spring means and said suction cup has a first chamber having said flexible rim thereon for engaging the heart said flexible rim being flexible in a plurality of planes to accommodate multiplanar movement of the surface of the beating heart without breaking contact between the surface of the heart and the flexible rim of the suction cup of said suspension head, a second chamber for fluidically connecting the first chamber of the suction cup of the suspension head to the source of suction, the second chamber of the suction cup of the suspension head having a size that is different from the size of the first chamber of the suction cup of the suspension head, and a shoulder at the connection between the first and second chambers of the suction cup of the suspension head, and said mesh grid element being connected to the suction cup on said suspension head adjacent to the shoulder of the suction cup of the suspension head and spanning the first chamber of the suction cup of the suspension head.

48. The system defined in Claim 17 wherein the head on said gross support means includes a proximal section and a distal section, with said proximal section being flexible.

49. A manipulation system for cardiac presentation in cardiac surgery comprising: a suspension means for suspending a beating heart in an unnatural position for surgery and which is located near the apical region of the heart and at least partially overlies the right ventricle of the heart and which includes means for attaching said suspension means to the heart and which accommodates multiplanar movement of the heart.

50. The system defined in Claim 49 further including a frame to which said suspension system is attached and which is located inside the patient during surgery.

51. The system defined in claim 49 further including a sternal retractor.

52. The manipulation system defined in Claim 49 further including a surgery target immobilizing means for engaging a selected section of the heart to immobilize that selected section as a surgery target while permitting non-engaged sections of the heart to move in a manner whereby essentially unabated cardiac output is maintained while the heart is locally immobilized.

53. The manipulation system defined in Claim 49 wherein the means for attaching the suspension means to the heart includes a suction cup having a rim which engages the myocardium and which moves in a plurality of planes in conjunction with movement of the myocardium to remain attached to the myocardium while the

heart beats.

54. The manipulation system defined in Claim 53 wherein the means for attaching the suspension means to the heart further includes means for accommodating multiplanar movement of the heart while the heart beats.

55. The manipulation system defined in Claim 53 wherein said suction cup includes means for engaging heart tissue to prevent that heart tissue from interfering with suction applied by the suction cup to the heart.

56. The manipulation system defined in Claim 55 wherein the means for preventing heart tissue from interfering with suction applied by the suction cup to the heart includes a mesh grid.

57. The manipulation system defined in Claim 55 wherein the suction cup includes a plurality of chambers.

58. The manipulation system defined in Claim 54 wherein the means for accommodating multiplanar movement of the heart includes a flexible element.

59. The manipulation system defined in Claim 52 wherein the surgery target immobilizing means includes a suction cup having a rim which engages the myocardium and which moves in a plurality of planes in conjunction with movement of the myocardium to

remain attached to the myocardium while the heart beats.

60. The manipulation system defined in Claim 59 wherein the surgery target immobilizing means includes a suction cup having a rim which engages the myocardium and which moves in a plurality of planes in conjunction with movement of the myocardium to remain attached to the myocardium while the heart beats.

61. The manipulation system defined in Claim 60 wherein the means for engaging heart tissue to prevent heart tissue from interfering with suction applied by the suction cup of the surgery target immobilizing means to the heart includes a mesh grid.

62. The manipulation system defined in Claim 52 wherein the surgery target immobilizing means includes an inflexible section for locally immobilizing a selected section of the heart, and a flexible section for attachment to the myocardium, said flexible section being flexible in a plurality of planes to accommodate movement of the myocardium during operation of the heart.

63. The manipulation system defined in Claim 49 further including a gross support means for supporting the mitral valve of the heart and lifting the heart and being located at the base of the heart at the left ventricle along the arterialventricular groove.

64. The manipulation system defined in Claim 63 wherein said

gross support means includes means for attaching said gross support means to the heart.

65. The manipulation system defined in Claim 64 wherein the means for attaching said gross support means to the heart includes means for applying suction to the heart.

66. The manipulation system defined in Claim 65 wherein the means of for attaching said gross support means to the heart for applying suction to the heart includes means for engaging heart tissue to prevent heart tissue from interfering with suction applied to the heart.

67. The manipulation system defined in Claim 66 wherein the means for attaching said gross support means to the heart for applying suction to the heart includes a mesh grid.

68. The manipulation system defined in Claim 63 wherein said gross support means further includes a handle.

69. The manipulation system defined in Claim 50 further including a gross support means for supporting the mitral valve of the heart and lifting the heart and being located at the base of the heart, said gross support means being attached to said frame.

70. The manipulation system defined in Claim 63 wherein said gross support means further includes a head that is flexible in

at least some sections thereof.

71. The manipulation system defined in Claim 70 wherein the flexible sections of the head of said gross support means is formed of material that maintains a second configuration after being deformed from a first configuration.

72. A method for manipulating a heart during cardiac surgery comprising:

engaging the heart near the apical region of the right ventricle and preventing collapse of the right ventricle;

lifting the heart into a position and orientation for surgery using the engagement near the apical region; and

maintaining engagement of the heart while the heart and its myocardium move during essentially unabated operation of the heart.

73. The method defined in Claim 72 further including a step of engaging the heart near the left ventricle along the arterialventricular groove.

74. The method defined in Claim 73 further including a step of lifting and rotating the heart to a preferred surgical access position while supporting the mitral valve annulus to maintain competent mitral valve function.

75. The method defined in Claim 72 further including a step of

immobilizing a surgical target of the heart while non-immobilized sections of the heart move to maintain essentially unabated cardiac output.

76. The heart manipulation system defined in Claim 17 wherein said means for locally engaging a selected section of the heart further includes a handle means which extends outside of the patient during surgery for adjusting the location and position of said means for locally engaging a selected section of the heart and moving the selected section into a desired position and orientation,